

OUR LEADERSHIP IN SCIENCE AND TECHNOLOGY AS PROVIDED BY THE NATIONAL SPACE PROGRAM

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Science and technology have made outstanding contributions to the dynamic success of the U. S. as a world leader. Our strength in developing products derived from our science research, much of which is traceable directly to new requirements called for in the space program, has given us a position of prestige and influence throughout the world. Let us first view some generalizations and then some specific examples of how the space program has helped to provide this leadership. First, the space effort has showed how large teams of scientists and engineers of varied disciplines could work together. Next, it has called for unheard-of reliabilities in the component parts and systems. Through our success in achieving these reliabilities, our country has led others in applying that same reliability to our civilian technological needs. The space program has also demanded minimum weight and size, and in developing the present-day mini- and microcomponents used in the space efforts, we were able to lead in designing, for our civilian technologies, more compact electronics, for computers and many other technological devices. Next, through our space exploration, by satellites, by deep space probes, and on the moon itself, this country has led in acquiring a better understanding of our environment and other aspects of our world. Finally, because of our ability to develop the large rockets and boosters needed for the space program, we can now raise very heavy objects to orbits 22 000 miles above the earth, and thus be able to watch on television, worldwide events as they occur, transmitted over our communications satellites. As the U. S. National Academy of Sciences President, Philip Handler, recently asked: "What can be a more powerful instrument in the search for a lasting peace than live satellite television communications around the globe?"

Let us now examine some specific instances of how science advances and new technologies, created as a result of space research, have been able to perform a valuable role outside of the space program. We shall discuss here only creative results. We all know that there is always a short-term coupling between the spending of Federal money and the nation's economy. But when the Federal funds can be made to find their way into truly creative

efforts, far greater long-time benefits have always resulted than when Federal money is simply used as an economic lever, as in various forms of Federal aid, in the use of Federal moneys for highways, etc., programs which all nations are undertaking.

The history of science and technology has shown that there are many examples where new technologies triggered vast areas of accomplishment in their wake extending over periods of time measured in decades. The Space Administration has been fully aware of science byproducts in its research and development activities and has been active in disseminating developments resulting from its scientific and technological programs. All significant scientific and technical papers and reports relevant to aeronautics and astronautics are identified. They include documents derived from NASA and its contractors, other branches of the Federal Government, and the aerospace activities of 40 foreign countries. The documents are microfilmed and indexed on tapes in data storage devices for quick access by interested users.

Probably the most important byproduct of the space program is the new knowledge gained in science. Historians tell us that there is an interplay among social needs, science, and technology. Each is necessary for progress in a technological society. Most scientists are agreed that advances in pure science are rapidly reflected in technological revolutions. Just as without the telescope, the science of modern astronomy would have been impossible, so without the rocket we could not now be pursuing science by sending instruments and men into the space environment.

New concepts and laws of science are much less predictable than are the applications which result from them. New observations made during space exploration can trigger chains of events extending well beyond our lifetimes and leading to unpredictably new scientific tools and concepts. Dr. Frederick Seitz, President of the Rockefeller University in New York, stated: "When future generations of mankind contemplate scientific knowledge made possible by the space program, they may well

wonder what manner of men the doubters were." Space technology increases the likelihood of observing new phenomena heretofore unobserved. Man can now take his scientific instruments and living organisms to places in the solar system and to new environments where he was previously forbidden.

One of the oldest problems challenging scientists is the structure of the universe; the distribution of the elements, the evolution of the stars, the formation of the sun and planets, and the origin of the earth. All the information we had about the universe prior to 1957 came to us in the form of waves radiated from the surfaces of stars that reached our telescopes and spectrographs after passing through the earth's atmosphere. Unfortunately most of this star radiation is absorbed in the atmosphere and a remarkably small fraction reaches our instruments. Now, for the first time, we have the means of putting our instruments beyond this atmospheric curtain to record the full sweep of radiation.

A major stimulus to science and technology is produced by the extreme environment of outer space combined with the requirements for low weight, small size, and exceptional reliability. We had this combination of requirements in aircrafts in the past but they did not approach the severity of the requirements for space vehicles. Obtaining the needed reliability in such complex systems poses an extremely large departure from past viewpoints and practices. Engineers used to be satisfied with modest reliabilities; the space program has developed attitudes among engineers so that much higher reliabilities, approaching 100 percent, are possible.

The space program has also furnished a new stimulus to imagination and creativity among engineers. This has come about perhaps because of the complexity of the problems to be solved and the lack of past experience. Designers faced with a set of entirely new constraints and no experience on which to draw were able to exercise their creativity in ways that were heretofore impossible.

The space program, and particularly the Apollo program, represents a uniquely different problem of management of large technological systems. In the past, there have been some massive engineering developments, but in the space program there are only a few items of each kind constructed, their complexity is greater, and the reliability which is required exceeds that of the past. For this reason it has been necessary to develop a system of

engineering management to specify what is wanted clearly and completely and to get it right the first time. The unusual successes in many space programs indicate that we are achieving higher levels of ability to develop, produce, and operate complex systems. There is a growing belief that the methods of systems analysis, systems engineering, and program management developed in the space program will have important application to social problems. Transportation, water management, medical services, ecology, and housing are areas where these methods should prove beneficial. It has been suggested that the gains in techniques for producing systems of ever-increasing reliability will eventually be worth many more times the cost of the space program.

Our space program has also been able to satisfy many of the needs of our society. Let me conclude, therefore, with a discussion of one outstanding example of how society the world over has benefited, and will continue to benefit in the decades to come, from a technological science development which is directly tied to space vehicles.

A satellite is uniquely qualified, by its line-of-sight feature, to be equivalent to a radio relay tower many thousands of miles high. It fulfills, therefore, the biggest difficulty of wideband microwave communications. Because of the earth's curvature, these signals are now relayed every 30 or 40 miles, a requirement which limited transmission to developed land areas such as those of the U.S. The several order-of-magnitude increment in relay tower height is, without question, one of the most significant advances in global communication technology. Accordingly, one of the greatest impacts of our space program is found in the field of communications. This is a consequence of our ability to place satellites in the one-revolution-per-day orbits called stationary orbits. Because the earth also rotates on its axis once every day, such satellites appear stationary with respect to the earth. Communications satellites are now "parked" in stationary orbits over both the Atlantic and Pacific Oceans, where they act as relays, receiving and sending television signals or hundreds of telephone conversations. It appears that such satellite links are much more economical than the earlier under-sea cable links, which further could not transmit television. Improvements in communications are extremely important because in the U.S. communications is a big business, a really big business. Our long distance telephone calls alone total almost \$5 billion a year. At this \$5 billion

per-year rate, if we could, for example, make twice as many calls at the same cost, we would be saving \$5 billion a year, more than the space program is now costing us. Our overseas calls (not including Mexico and Canada) total almost a quarter of a billion dollars, and satellites now parked over the Atlantic and Pacific are already relaying a large fraction of these calls.

Now the economics for satellites for telephoning are rather startling. The wholesale charge to telephone companies of a transoceanic voice channel via satellite is only 10 cents per minute. So, our telephone costs are destined to come down. Furthermore, satellites are providing us with something heretofore unavailable — live television coverage of many worldwide events. Communications within nations are also due to benefit soon. In late 1970, COMSAT proposed a \$114 million domestic U.S. communications satellite system to be leased to the American Telephone and Telegraph Company for a reported \$29.5 million a year. Its capacity of 10 800 voice circuits results in this lease charge, for full usage, being equivalent to approximately one-half cent a minute for a cross-country, long distance call.

On September 18, 1969, the Indian Department of Atomic Energy and NASA signed a Memorandum of Understanding to conduct a joint instructional television experiment using the Applications Technology Satellite (ATS-F). This experiment will provide the technology to overcome India's lack of broadband telecommunication links throughout the country and disseminate instruction and information to rural, remote areas, where 80 percent of her population lives.

The Indian Government studied the cost and significance of establishing a powerful national mass communication television system using a synchronous satellite to link rural communities and distant centers of population. For further study, they installed community television receivers in 80 villages around Delhi. In this system many small villages will receive the signal directly from ATS-F. In densely populated areas, sets will receive a signal from local stations which rebroadcast the signal they receive from the spacecraft.

But we should not judge the value of our space research from the practical results alone, extensive as they may be. There may often be hidden values of far greater importance. As success breeds success, excellence breeds excellence, and the great demands for quality and excellence which the space program places on its equipment, its planning, and its functioning, these provide a magnet for attracting talented scientists and engineers to the program. The key to future advances in technology and to an advancing prosperity for our society will continue to be an emphasis on the search for new knowledge. Many critics of the space program have been saying that the funds spent for space would be better spent right here on earth. You probably know Wernher von Braun's story of the little old lady, sitting on her porch in her rocking chair. When asked if she was ever going to ride an airplane, she responded, "No siree, I'm just going to stay right here on earth and watch television, like the good Lord intended." Well, now she can watch worldwide television!